With the Author's comp.ts

7

J F Campbell

May 23 1876

THE

ICE AGE IN BRITAIN.

RALPH RICHARDSON, F.R.S.E.

SECY. G.S.E.

7

THE

ICE AGE IN BRITAIN,

CONSIDERED IN RELATION TO THE

DEPTH OF THE NORTH ATLANTIC OCEAN

AS DETERMINED BY RECENT AND EARLIER
DEEP-SEA SOUNDINGS.

BY

RALPH RICHARDSON, F.R.S.E.,
HON. SEC. EDINBURGH GEOLOGICAL SOCIETY.

EDINBURGH:
MACLACHLAN AND STEWART, 64 SOUTH BRIDGE.
MDCCCLXXVI.

One Shilling

PREFACE.

THE substance of the following Paper was read before the EDINBURGH GEOLOGICAL SOCIETY in two portions—the first on 23d March 1876, under the title of a paper "On the North Atlantic Ocean-Bed;" and the second on 6th April 1876, under that of "A Theory of the Cause of the Great Glacial Epoch, particularly in Britain." Dr JAMES BRYCE, F.G.S., presided on both occasions. The papers were favourably received, and awakened some interest and discussion; and in presenting them now in a more compact and complete form, it is hoped the subject may prove interesting to a wider circle.

R. R.

35 CASTLE STREET, EDINBURGH,
15th April 1876.

THE

ICE AGE IN BRITAIN.

THE soundings which have been made in the North Atlantic Ocean at various dates, and the last of which are those taken by H.M.S. "Valorous," which returned to England on 29th August last, after a cruise to Disco Island, enable us to have some idea of the form of the vast ocean-bed. We have it now mapped out before us with as much precision as the broader outlines of the land-surface on a physical map.* The popular idea that the bed of the ocean sweeps, in a more or less regular curve, from shore to shore, is confuted by such diagrams as these, which demonstrate that, as on land, so at the bottom of the sea, hills and dales, plains and valleys follow each other with a variety and irregularity which can only be accounted for by the convulsions of the past. It may not be uninteresting to glance at the general features of the bed of the North Atlantic, as revealed by the patient labours of those who have sounded its depths in so many places; and I may be permitted to conclude the present paper by noticing some points of especial interest to geologists in connection with the relation of the depth of the ocean, and of the seas around our own coasts, to the Glacial theory.

As to the general features of the sea-bed of the North Atlantic Ocean, it is to be remarked that, roughly speaking, the deepest portions are those most remote from land. As Mrs Mary Somerville expresses it in her "Physical Geography":†

* Models illustrative of physical geography could now be constructed indicating the depth of the seas as well as the heights of the mountains.

† Sixth edition, 1870, p. 220.

"Throughout the North Atlantic, the land *shelves down* to greater and greater depths gradually on both sides." All round the shores of Newfoundland, Labrador, Greenland, Iceland, and the British Isles, the water is comparatively shallow. There may be said to be six zones of depth in the North Atlantic: the *first*, up to 100 fathoms, skirting the shores of the countries I have named; the *second*, from 100 to 500 fathoms, being further out to sea; the *third*, from 500 to 1000 fathoms, being still further seaward; followed by the *fourth*, from 1000 to 1500 fathoms; the *fifth*, from 1500 to 2000 fathoms; and *lastly*, the central zone, being the deepest of the six, and ranging from 2000 to 2600 fathoms. It is interesting to note with what regularity these six great zones encircle one another, until at last, near the centre, they terminate at the deepest parts of the ocean. They recall to mind, on the terrestrial map, some low-lying valley from which the land slowly rises on all sides over a vast expanse. In fact, were the bed of the North Atlantic laid dry, we should find in what I have termed its sixth zone of depth a very low-lying district, and we should gradually ascend higher and higher, until at last we came to Canada on the west, Greenland on the north, and Britain on the east, each of these countries occupying elevated tracts of country no less than from 12,000 to 15,000 feet above the level of the low-lying portions from which we started. That is to say, the coast of England is about as high above the level of the deepest part of the North Atlantic as the summit of Mont Blanc* is at present above the level of the sea.

I should mention that the sixth or deepest zone of the North Atlantic is found in three portions, two of which are situated almost in the middle of the ocean, whilst the third and smallest portion lies more to the east. The soundings that have been made in the last-mentioned or most eastern of these three portions gave 2623 fathoms as the depth at one place; in the central portion the soundings were 2000, 2070, and 2400 fathoms; and in the western portion 2250, 2385, and 2425 fathoms; whilst at the most northern extremity of this portion, not very far from the southern extremity of Greenland, the depth was found to be 2032 fathoms. On the whole, the depth

* Stated by Mrs Mary Somerville to be 15,784 English feet high, *op. cit.* p. 531.

of the sixth zone, as ascertained from these soundings, ranged from 2000 to 2600 fathoms. The soundings in question were made in the more northerly part of the area of the North Atlantic.

Vessels such as the "Valorous" and others, bound for the Arctic seas, do not pass over the deepest portions of the North Atlantic, holding a more northward course. Thus the soundings of the "Valorous" (which are the most recent yet made) do not give us the greatest depth of the ocean. They were made in the second, third, fourth, and fifth zones, but not in the first or sixth, the cause of the absence of the former being perhaps because they had mostly been already ascertained, and that of the latter because of lack of opportunity. Among the most interesting of the soundings of the "Valorous" was that made on 20th August last, in mid-ocean, lat. 56° 2′ N., and 34° 51′ W. Here a patch of the third zone was found in the midst of an immense expanse of the fourth, the soundings showing a depth of only 690 fathoms in the midst of an encircling zone of from 1000 to 1500 fathoms. The cause of this patch or submerged elevation may possibly be ascribed to igneous agencies, for I observe that "black volcanic stones" were brought up at this place, whereas "mud" or "ooze" seem to have been chiefly dredged elsewhere. As regards the covering of the sea bottom, as revealed by the dredgings of the "Valorous," it would appear that the deepest soundings, viz., 1785* and 1860† fathoms, found the bottom covered with "ooze," which, I may remark parenthetically, Professor Wyville Thomson considers not merely a repetition, but the actual *continuation* of the Cretaceous formation to the present day,‡ the revolutions to which the other more exposed

* Lat. 55° 10′ N., long. 25° 58′ W.

† Lat. 57° 50′ N., long. 44° 52′ W.

‡ *Cf.* M. R. Vion, in the "Bulletin" for February 1876, of the Société Linnéenne du Nord de la France; also Professor Prestwich, F.R.S., in his Presidential Address to the Geological Society of London, 17th February 1871. There is a possibility that during the Cretaceous epoch a great body of water (termed by Prof. Prestwich a "chalk ocean") stretched through Central Europe, and from the south-west of England, west of France, and north of Ireland, across the deepest portions of the Atlantic, to the south-east of North America. The eastern and western portions of the bed of that ocean have been upheaved, and exhibit what is termed geologically the Cretaceous formation. The central portions of the bed of the old chalk ocean may possibly be represented by the ooze-covered profoundest depths of the Atlantic, which may never have been disturbed to this day.

portions of the world were subject being unfelt at these profound ocean depths. At lesser depths, from 1100 to 1400 fathoms, "mud," or "clay and mud," were found to be the covering of the sea-bed. "Fine sand" was found in one sounding at a depth of 1660 fathoms. The "Valorous" made eleven soundings in all, four down the centre of Davis' Strait, and seven over an unexplored area of the North Atlantic, between the lines of the "Bulldog" and "Cyclops."*

The extraordinary irregularity of the bed of the North Atlantic may be judged from the results of the soundings of the "Valorous." I have already alluded to the peaked volcanic hill which was discovered suddenly rising in the midst of surrounding depths. This hill, or rather mountain, rises to a height of 7020 feet above the deepest soundings taken on either side; and the gradual slope downwards of its sides was proved by three soundings, one on its western flank and two on its eastern, the area occupied by this submarine mountain extending from lat. 57° 50′ N., long. 44° 52′ W. to lat. 55° 10′ N., long. 25° 58′ W. At the same time we must recollect that, lofty as this mountain may be from the bottom of the surrounding sea, its summit or peak is 690 fathoms below the surface of the ocean. Such is the interesting submarine "Mount Valorous."

Whilst the greatest depths of the North Atlantic are towards the centre of the ocean, the most shallow portions are towards the north. Thus, taking Greenland as a centre, we find that, on the west, all Davis' Strait belongs to the second zone of depth, or only from 100 to 500 fathoms. Next the shores of Greenland the depth becomes still less. Then on the east and south of that continent all the great expanse of sea stretching past Iceland and the Faroe Islands to Britain and the continent of Europe is comparatively very shallow, never exceeding 1000 fathoms, and mostly not exceeding 100. One tract of sea, extending in a straight line from the east coast of Greenland *via* Iceland and Faroe to Scotland, does not exceed in depth 500 fathoms. All round the coasts of Greenland, Iceland, the Faroe Isles, and the United Kingdom, the depth does not exceed 100 fathoms. "The depth of the sea in the English Channel is,"

* See the "Geographical Magazine" for October 1875, to which I am indebted for these facts.

says Dr James Croll,* "only about 20 fathoms," and "the average depth of the entire North Sea is not over 40 fathoms," or 240 feet. Let us keep these facts in mind from a geological point of view. Let us especially bear in mind that there is a broad tract, presently covered by the sea, and stretching directly from Greenland *via* Iceland and Faroe to Britain, the depth of which never exceeds 500 fathoms, or 3000 feet; and let us also observe that, as compared with the central portions of the North Atlantic, all the north-eastern portion—in a word, that portion situated between Greenland and this country—is a shallow sea.

My object in directing attention to these points is to endeavour to gather from them some clue to the origin and history of the great Glacial epoch in Britain. I need not enter into any details regarding that extraordinary epoch, which has given rise to so much discussion. It is generally believed that during it our country and a large portion of Europe were buried in ice and snow, and were subject to conditions such as are now to be met with only in a continent like Greenland, which, in the language of Dr Robert Brown, is covered by an "icy pall, north and south, east and west, far as the eye can see, or the observations of the few explorers who have attempted to penetrate it have enabled us to judge."† Dr Croll estimates the thickness of the ice-sheet at the centre of Greenland to be 10,000 feet.‡

Sir Charles Lyell, followed by other geologists, have stated it as their opinion that some decided change in the physical geography of the northern hemisphere is necessary in order to account for the occurrence of a Glacial epoch. Now, the soundings of the North Atlantic, between the continents of Europe and Greenland, seem to me to favour the hypothesis that there was, during the intensest period of the great Glacial epoch, an elevation of the sea-bed there; for, as I already have observed, that portion of the ocean is comparatively one of the most shallow. There would in that case be land instead of sea

* In "Climate and Time in their Geological Relations," 1875, p. 442.

† "Geological Notes on the Noursoak Peninsula, Disco Island, and the country in the vicinity of Disco Bay, North Greenland."—*Trans. Glasgow Geol. Soc.*, vol. v. part i. 1875.

‡ "Geological Magazine," July and August 1874.

between Greenland and Britain; in other words, Greenland and Europe would be united and form one continent.

In suggesting the junction of Britain (and Europe) with Greenland by the elevation merely of the intervening tract of the North Atlantic, I have already stated that that tract is at present of a depth of less than 500 fathoms. Many portions of the tract in question would require a much smaller elevation. Lest, however, any should regard with disfavour the theory of elevation simply because of its extraordinary character, I may remind them, *first*, that extraordinary means are necessarily implied in the production of so extraordinary an epoch as the Glacial; and *second*, that in the opinion of one of the most cautious and uniformitarian geologists, the late Sir Charles Lyell, the continent of Europe has been subject to the converse phenomenon of depression on a vast scale since the commencement of the Eocene period. In a map, with which readers of that great departed geologist's "Principles"* will be familiar, it is shown that since the commencement of the Eocene period (which occurred, geologically speaking, not so very long before the Glacial), an enormous territory, stretching across Europe from Holland, through Hanover, Prussia, and Russia, to the White Sea on the north, and the Caspian on the south-east, has been submerged.

Such oscillations in the level of the land, termed elevations and depressions, are admitted to have taken place repeatedly during the more recent geological epochs. As to the Glacial period in particular, "there were," says Lyell, "great changes in the form of the earth's crust, many movements of upheaval and subsidence, and many conversions of sea into land, and land into sea, during the Glacial epoch."† "In one part of the Glacial period," he also remarks,‡ "we find proofs that England and Ireland were united to each other and to the continent, while at other times they were broken up into an archipelago of small islands; we also find that large parts of Northern Germany and Russia were beneath a sea often covered with floating ice. . . . In short," he concludes, "a map of the northern hemisphere, even in Glacial times, would bear but a distant resemblance to our present maps of the same region." The proofs of such great geographical

* Tenth edition, 1867, vol. i. p. 251. † *Op. cit.* p. 197. ‡ *Op. cit.* p. 250.

revolutions lie ready to hand. "By aid of *marine drifts*," says Lyell,* "great oscillations in the level of the land since the commencement of the Glacial epoch were proved to have taken place. The change of level in Scotland, as demonstrated by this kind of proof, amounts to 500 feet, in some parts of Central England to 1200, and in North Wales to 1400 feet,—these movements having all occurred in post-Tertiary times, or within the period of the living testacea. But Professor Ramsay infers, from the position of the stratified drifts of the Glacial period in North Wales, that the full extent of the vertical movement which brought about first the submergence and then the re-emergence of the land, exceeded 2000 feet."†

So much for the oscillations to which the land we now know was subject. Without such a depression as Sir Charles Lyell alludes to, the marine drifts found in our country could not be accounted for. Again, without some such *elevation* as I have referred to, the Glacial epoch itself in Britain seems to me difficult to explain. It is almost impossible to believe that Britain, in its present insular condition, was subject to that great moving ice-sheet which once covered the land, and whose polishings and groovings are visible to this day. Such an ice sheet must, I prefer to think, have had its origin and gathering ground in polar regions, and have descended southwards over Britain, Scandinavia, and Northern Europe. If this theory be correct, then there must have been a junction of Greenland with Iceland, Faroe, and Britain.

There is another consideration favouring the idea of the terrestrial condition at one time of the tract between Greenland and Britain. Such a change would be productive of intense cold. Not merely would the ice-mass covering Greenland obtain means of access to this country, and of itself lower the temperature,‡ but the mere fact that the sea would be shut out

* Sir Charles Lyell's "Principles of Geology," p. 195.

† *Vide* also Prof. Ramsay's "Physical Georgraphy," 1872, p. 154.

‡ The effect of even an iceberg stranding on a coast is so great as to change the temperature in its vicinity. Speaking of Greenland icebergs stranding on the Irish coast, Lyell says—"The inhabitants are then aware that their crops of hay will fail in consequence of fogs which are generated almost incessantly; the dearth of food is not confined to the land, for the temperature of the water is so changed that the fish entirely desert the coast."—*Principles*, i. 245.

from North-Western Europe would intensify the cold. Above all, that current known as the Gulf Stream, which at present flows towards our coasts, and tends to render our climate warmer and more equable than otherwise, would cease to have any influence, and would have to take another course. "Meeting the British Islands," says Lieutenant Maury, "the Gulf Stream is divided by them; one part going into the polar basin of Spitzbergen, the other entering the Bay of Biscay, but each with a warmth considerably above the ocean temperature. Such an immense volume of heated water cannot fail to carry with it beyond the seas a mild and moist atmosphere. And this it is which so much softens climate there."* Now, the removal from Britain and North-Western Europe of this source of heat would of itself effect a revolution in temperature.

In the charts exhibiting the soundings of the North Atlantic, and proving the comparative shallowness of the sea between Greenland and Britain, we observe that a vertical movement of elevation, of no greater extent than that which occurred during the Glacial epoch, would be sufficient to unite Europe and Greenland. Professor Ramsay and Sir Charles Lyell † agree in thinking that our country was, during the Glacial epoch, subject to a depression exceeding 2000 feet. Then were deposited the *marine drifts* already referred to. But previous to our country being so submerged, occurred the period of land-ice, during which the intensest glacial, and truly Greenland, conditions prevailed, and then, I submit, Britain and Greenland, or rather Europe and Greenland, formed one continent. Had the intermediate tract of the North Atlantic, lying between Greenland and Europe, embraced one or more of the deeper zones of soundings, such a theory of elevation as I have submitted would, on account of the great vertical movement required, have been difficult to maintain. No more, however, than the same vertical movement which first depressed and afterwards

* "Physical Geography of the Sea," 6th edition, 1856, p. 37. See also Lyell's "Principles," i. 245, for Forbes' and Scoresby's opinions. See also Mr Cooley's recent work on "Physical Geography," 1876, for a review of Maury's and Croll's views.

† Several interesting maps, illustrating the elevation and subsidence of the British Isles, and North-west Europe, are given in Lyell's "Antiquity of Man," 4th edition, 1873, figs. 42, 43, and 44.

upheaved Britain during the middle and later stages of the Glacial epoch would be required to convert the space around our shores, and northwards to Greenland and Scandinavia, into dry land again. The very deepest portions of the intermediate tract are 500 fathoms, or 3000 feet, but an elevation of above 2000 feet would unite the two countries, for the average depth cannot be above 300 fathoms, or 1800 feet. To account for the deposition of the marine drifts, Professor Ramsay and Sir Charles Lyell have suggested that Britain was *depressed* to an extent exceeding 2000 feet; and to account for the glaciation of Britain and Europe, I have suggested that the tract between Europe and Greenland was *elevated* to an extent exceeding 2000 feet. It is no unwarrantable hypothesis to take for granted that the "vertical movement, exceeding 2000 feet," to which Professor Ramsay gives his high authority, was not confined to the British Isles, but extended beyond them, possibly in the direction of Greenland and Scandinavia, and that it connected Britain with polar regions, by elevation of the sea-bed, during one portion of the Glacial epoch. The fact that the tract between Greenland and Britain is now submerged, whilst the British Isles are elevated, only proves the irregularity with which those mysterious forces work, that contract or expand our earth's crust, and give rise to the striking geological phenomena of depression and elevation.

As is well known, Sir Charles Lyell considered that "changes in physical geography, or in the position of land and sea," "must always have exercised a dominant influence" on "those variations of climate to which geology bears testimony."* He likewise believed an "excess of polar land" to be "*essential*" for the production of such an "exaggeration of the cold of both hemispheres" as would give rise to a Glacial epoch.† The illustrious Humboldt, too, observes that "the principal cause of the greater intensity of cold in corresponding latitudes of North America, as contrasted with Europe, is the connection of America with the polar circle by a large tract of *land*, some of which is from three to five thousand feet in height; and, on the other hand, the separation of Europe from the arctic circle by an ocean."‡

I do not mean to assert that the simple terrestrial union of

* "Principles," vol. i. p. 268. † *Ibid.* p. 291. ‡ *Ibid.* p. 236.

Greenland and Europe would clothe the northern portions of the latter with that immense covering of ice in which the former lies buried. I think it probable that we must look to some other influences besides those purely connected with physical geography. The climate of Northern Europe was probably rendered severe during the Glacial epoch, not merely by the glacial state of the land and the absence of marine influences, but also by the diminution of the sun's influence upon our planet, just as during some previous geological periods the reverse occurred, and, as our coal forests testify, this country enjoyed remarkable warmth and luxuriant vegetation. Even Greenland itself, as Professor Heer has shown, "once knew a genial climate, with large-leaved trees, and a high summer temperature."*

In an important work published during the past year,† Dr James Croll, whilst advancing his well-known theory, based on astronomical considerations,‡ also favours the idea of the union at one time of Greenland and Northern Europe; only he appears to think that what is now sea might have been filled or "blocked with solid ice," which, owing to its immense thickness, was not "able to float in the North Atlantic."§ He says that "the ice moving off the Antarctic continent must be in some places considerably over a mile in thickness." Dr Croll suggests that "the seas around Scotland, owing to their shallowness, were, during the Glacial period, blocked up with solid ice. Scotland, Scandinavia, and the North Sea would form one immense table-land of ice, from 1000 to 2000 feet above the sea-level. This table-land would terminate in the deep waters of the Atlantic, by a perpendicular wall of ice extending probably from the west of Ireland away in the direction of Iceland."‖ Thus the difference between Dr Croll's views and my own seems only to be

* Professor Heer cited by Lyell. "Principles," i. 203.

† "Climate and Time in their Geological Relations," 1875.

‡ Dr Ricketts, F.G.S., does not think this theory is adequate to account for glacial conditions in the British Isles and Eastern Europe. "The diversion of the Gulf Stream," he says, "is upon all hands considered sufficient to produce all those effects which occurred in Britain during the Glacial Period;" and he alludes to the probability of the Gulf Stream once escaping into the Pacific by the submergence of the Isthmus of Panama.—*Geological Magazine*, December 1875. Mr S. Newcomb of Washington, in the "American Journal of Science and Arts" for April 1876, also criticises Dr Croll's theory adversely.

§ *Op. cit.* p. 452. ‖ *Ibid.*

that, whilst he apparently thinks the union of Europe and arctic regions may have been effected by ice alone, I have suggested that there was an elevation of the sea-bed, and a consequent extension to Britain of the land-ice presently covering high latitudes.

We must not, however, forget that the converse phenomenon of depression, leading to the subsidence of the deeper parts of the Atlantic, would produce the very same result. "Were the Atlantic," says Herschel,* "to sink another thousand fathoms (to the 3000 fathoms level line), the whole of the European and African side of its bed would be laid dry. The table-land"—known as the Telegraphic Plateau,† from Cape Race in Newfoundland to Cape Clear in Ireland—"would form an extension of the European continent. The British Islands and the north of Europe would become united with the Labrador coast, and nothing would remain of the ocean but a comparatively narrow channel, following at no great distance the present line of the American continent." Professor A. E. Nordenskiöld of Stockholm says, with reference to the *Miocene* era, that "there are many reasons for supposing that the continents of Europe and America were at that time united, and bounded on the south by an ocean, extending from the Atlantic, over the present deserts of Sahara and Central Asia, to the Pacific."‡ As to the subsequent *Pliocene* and *Glacial* eras, Professor Prestwich, chiefly on palæontological grounds, came to the conclusion, "that the bed of the North Atlantic may have been from 1500 to 1600 feet, or more, deeper during the Pliocene and Glacial period than it now is."§ The comparative shallowness of the waters of the North Atlantic, between Greenland and Europe, seemed to me to favour the hypothesis of elevation, although, undoubtedly, subsidence at greater depths, as alluded to by Herschel, would produce much the same result. With regard to the glaciation of North America, I observe that Professor James D. Dana stated very recently that he considered it was due to the Gulf Stream and its attendant heat having been confined "to the temperate

* "Encyclopædia Britannica," 8th edition, 1859, Art. "Physical Geography."
† Maury, *op. cit.* p. 308; Mrs Somerville, *op. cit.* p. 220.
‡ "Geological Magazine" for November 1875.
§ Presidential Address cited *supra*.

and tropical North Atlantic by a *shoaling of the ocean* between Scandinavia and Greenland."*

Another consideration remains to be mentioned, and deserves, I think, to be kept in view in speaking of the elevation or depression of the sea-bed between Britain and the polar regions. That sea-bed is situated upon the great volcanic line which skirts the extreme west of the Old World, and which, according to Mr W. L. Watts, "extends from Jan Mayen"—an island lying between Iceland and Spitzbergen—"through Iceland, the Faroes, Great Britain, the Madeiras, the Azores, Cape de Verdes, the Canaries, and, breaking out along the west coast of Africa, terminates at Tristan da Cunha."† The Tertiary volcanoes of the Hebrides are, in Mr Judd's opinion,‡ situated upon the same line of volcanic action. In fact, this line seems to be one of those weaker portions of the earth's crust upon which the subterranean forces operate most easily; and hence not only eruptions, but also movements of elevation or depression occurring here are not so unaccountable.

Finally, although I have dwelt chiefly upon the necessary union of Europe with the polar regions to account for the ice mass which, I believe, covered the more northern portions of the former during the earlier and intensest period of the Glacial epoch,—as it does not seem possible that an island like Britain, for example, exposed as it is to the influence of the Gulf Stream, could have maintained such an ice mass whilst in an insular condition as at present,—I ought not to omit to mention, that geological evidence appears to prove that we must look to the north for the great source of glaciation and motive power during the Glacial epoch. The *striæ* upon the rocks of Iceland seem, according to Robert Chambers, to point towards North Greenland.§ Those on the rocks of the Faroe, Shetland, and Orkney Isles "all point," according to Dr James Croll, "in the direction of Scandinavia."‖ Scandinavia, however, was perhaps not the

* "American Journal of Science and Arts" for November 1875.

† "On the Volcanic Geology of Iceland."—*Pro. Geologists' Association*, London, vol. iv. p. 214.

‡ "Quart. Journal Geol. Soc." vol. xxx. p. 275.

§ Croll on "Climate and Time," cited *supra*, p. 451.

‖ *Ibid.* p. 450, Dr Croll gives a chart of the probable path of the ice in North-Western Europe.

great peninsula we now know, for Professor Nordenskiold, in treating recently of Spitzbergen, thinks it probable that that island, during the Glacial period, formed part of "a considerable Arctic continent, which, towards the south, was connected with Scandinavia, and towards the east with continental Siberia."* In December last, at a meeting of the Edinburgh Geological Society, Dr James Bryce, F.G.S., and Mr Jolly of Inverness, both of whom had minutely examined the rocks of the Outer Hebrides, expressed their opinion that the agent which had glaciated the Lewis had proceeded from some land to the west now submerged,—Mr Jolly remarking, that the *striæ* on the rocks of the western coasts of the Lewis could be seen coming up out of the waters of the Atlantic, and that, whilst the eastern sides of these rocks are rough and truncated, the western are smooth and regularly polished. The opinion expressed by such very competent geologists, that land once existed to the west of the Outer Hebrides, is quite in unison with such a theory as I have stated, and which is founded upon the conclusion come to by Lyell, that there must have been a very material difference between the physical geography of the Glacial period and that of the present day. I may add that Mr James Geikie, F.R.S., shows, in a map in his "Great Ice Age," that if the sea-bed to the west of Scotland were elevated only 600 feet, the coast line would be found twenty miles to the west of the remote island of St Kilda.

Again, as to the dispersion of *erratics* (although these, of course, were transported by floating ice subject to marine currents) the borders of the Baltic are, according to Sir Charles Lyell, covered "for hundreds of miles east and west" with a deposit of till, full of "erratic blocks, often of very large size, of northern origin" derived from Norway, Sweden, and Finland.† In our own district of Edinburgh, the agent which has striated and polished our rocks seems to have passed over them chiefly from the north-west. As to the dispersion of *erratics* in Lowland Scotland, I may just instance the curious "White Stone" of Peebles (of which I read a notice before the Edinburgh Geological Society in 1874),‡ a quartz erratic that must have been derived from the Highlands.

* "Geological Magazine" for January 1876.

† "Antiquity of Man," cited *supra*, p. 274.

‡ *Vide* "Transactions of the Edinburgh Geological Society," vol. ii. p. 397.

At the same time, we must guard ourselves from supposing that the ice of the Glacial epoch moved only in one direction, and that a southerly one. Mr James Geikie, in his very interesting and valuable work on the Ice Age,* has shown that the principal lines of Glacial erosion in Sweden, Norway, and Finland (of which he gives a map) sometimes trend in an easterly or westerly, as well as in a more southerly direction. A body of ice, like a body of anything else, will follow the line of least resistance at all times. Still, it appears to me that we cannot avoid the conclusion that such an enormous mass of ice as enveloped our country in Glacial times, had, like the climate that produced it, a northern origin; that it was alimented and impelled by northern and much greater masses of ice; and that unless it had had such a connection with polar regions,—in other words, if the physical features of Europe had been the same then as they are at the present day, the Glacial epoch would not have occurred.

Permit me, in conclusion, to recapitulate the leading points which I have brought under notice in this paper, and to state briefly the line of argument I have followed.

1st, We learn from geological evidence that, towards the opening of the Glacial epoch, the most intense period of cold occurred, and that Britain was, in all probability, then covered by an ice-sheet like the interior of Greenland at the present day.

2d, Such an ice-sheet could not be formed if Britain were surrounded by the sea as at present, and exposed to the influence of the Gulf Stream.

3d, Such an ice-sheet could only be formed were Britain removed from marine influences, and connected with the polar regions.

4th, Deep-sea soundings prove that that portion of the ocean betwixt arctic regions and Britain is comparatively one of the shallowest parts of the North Atlantic, its depth being such that the same vertical movement which occurred during the middle of the Glacial epoch would convert the present sea-bed into land.

5th, Geological evidence proves that great oscillations of the land took place during the Glacial epoch, affecting Britain and Northern Europe generally.

* "The Great Ice Age," 1874, p. 382.

6*th*, It is suggested that one of these oscillations had the effect of uniting Britain and Northern Europe with Greenland and the arctic regions.

7*th*, The effect of such an union would be to give the polar ice-fields access to Europe; to divert the course of the Gulf Stream, and free North-Western Europe from its influence; and, in conjunction probably with some diminution in the influence of the sun, to produce a Glacial epoch.

Note to page 17.

DIRECTION OF STRIÆ.

At a meeting of the Edinburgh Geological Society, held on 11th May 1876, the President, Mr Milne Home of Wedderburn, LL.D., F.G.S., stated that the result of the examination of the *striæ* on the rocks of Caithness and Sutherlandshire, by Robert Chambers, Mr Jamieson of Ellon, and Mr Campbell of Islay, had been to show that the agent which had striated these rocks had passed over them from the north-west, that is to say, from the present line of sea-coast inland. Mr Milne Home added, that the map given by Mr James Geikie in his "Great Ice Age," indicated that the striating agent had passed from the interior to the sea, whereas the opposite had been the result of Messrs Chambers', Jamieson's, and Campbell's examination of the rocks. I append this Note (printed after this Paper had gone to press,) as corroboratory of the evidence regarding the striation of the rocks of the Outer Hebrides given by Dr Bryce and Mr Jolly, referred to at page 17, to the effect that the glaciating agent came from land to the west *now submerged*, a theory in keeping with that advanced in these pages, viz.—that during the Ice Age in Britain the geographical features of our country and of the northern hemisphere were quite different to what they are at present.

R. R.

PRINTED BY NEILL AND COMPANY, EDINBURGH.